EXHIBIT I

FAX COVER SHEET

TO	Doug Lewis
COMPANY	Sidley Austin
FAX NUMBER	13128537036
FROM	brian von herzen
DATE	2004-01-05 03:20:11 GMT
RE	IEEE Reference (1988) covering software video compression

COVER MESSAGE

Doug:

Attached is an IEEE article from 1988 covering video compression software
and hardware-- page 1 states that it takes 30 seconds to compress a frame
using a VAX computer, and 3 seconds using a 64-processor supercomputer
(pages 45 and 46). We should plan to discuss this article by phone
Monday. Please let me know when you are available.

Thanks,

Brian Von Herzen
775-790-5000

You are there... and in control

By reconstructing video signals from highly compressed versions, in real time and at affordable costs, a new system offers viewers unprecedented interaction

ADVANCED TECHNOLOGY

CONSUMER ELECTRONICS

Powerful new techniques for compressing digital video data could soon lure viewers from ringside seats into the very heart of the action, controlling and even manipulating what they see and hear on-screen. Until now, digitizing motion realistically for video produced data streams of 10 to 20 megabytes per second. Even the most powerful minicomputers and mainframes would be hard-pressed to store and process data at such high rates.

But compressing the data before it is processed and stored reduces the data rate so much that personal computers (PCs) can handle it, bringing digital interactive video within the reach of today's small businesses and tomorrow's ordinary consumers. The compressed data can readily be stored on a convenient, easily handled medium such as a compact disk (CD).

An obvious application of digital interactive video is helping and training computer users. Images of real people appear on the video monitor to advise and guide users with realistic voices. The users can try alternative operations or back up to earlier operations, always getting the appropriate response from their interactive mentors.

Interactive video also makes entirely new applications possible, such as surrogate travel and synthetic video. In surrogate travel, a PC presents the sights and sounds of distant places, letting a user roam "there" at will [Fig. 1]. The user chooses paths with a mouse or joystick, and the PC responds with the appropriate audio and video, prerecorded on location.

In synthetic video, a PC contrives realistic, detailed images from mathematical models, using algorithms to attach textures and colors to selected areas of the images. Synthetic video lets architects display houses and interior designers display rooms quickly and far more realistically than ordinary graphics software would [Fig. 2]. In flight simulators, synthetic video shows a fairly convincing view from a cockpit as a simulated plane flies over computer-modeled terrain. A PC does all this with only simple mathematical models. The details—the textures, colors, and color gradations—are photographed or drawn, digitized, compressed, and stored for the computer to shape and combine as necessary.

Why digital?

Analog television, unassisted by computers, does not allow a viewer to interact with it. It delivers programming with low-cost equipment to many people at once, and there is no way they can change the course of what they see and hear. Even with a videocassette recorder as the programming source, viewers can only forward, reverse, or hold images.

With a computer-controlled laser videodisk, analog video achieves a measure of interactivity (LaserVision is an example). A viewer can at least choose alternative paths through the programming (by selecting from a list of multiple choices in a training session, for example). But such systems are expensive and often cumbersome, and their adherence to analog technology limits the way in which images can be manipulated.

Only fully digital systems allow complete interaction. They can be programmed in myriad ways to respond to a user's choices, and they can access data at random. They can employ a PC as the controlling element—equipment that individuals and small businesses can readily afford, and that large companies buy in great quantities. Although PCs usually produce highly artificial images and sound (as in video games), new data compression techniques give their images and sound a realism that rivals that of analog television.

Digital interactive video is at or close to commercial application in at least two versions. A system called CD-I (for compact disk interactive) has been developed jointly by NV Philips of Eindhoven, the Netherlands, and Sony Corp. of Tokyo (see "DVI versus CD-I," p. 47), and will be marketed by a variety of licensees. The David Sarnoff Research Center, Princeton, N.J., funded by General Electric Co., Fairfield, Conn., has developed what it calls DVI (for digital video interactive) technology. DVI is undergoing field tests at about 20 sites, in applications ranging from engineering design to retailing.

Digital video is not new, of course. Broadcast television studios use it to manipulate images, and telecommunications companies use it for their teleconferencing services. Studio equipment costs upwards of $30 000, however—much too expensive for a single user. The new interactive systems, in contrast, are aimed at large markets. GE's DVI system, for example, costs less than $10 000 and may eventually drop to about $1000 when production volume reaches consumer quantities.

Compressing sound and image

Video compression requires a lot of processing. It usually takes a large computer many hours to achieve the degree of video compression needed by a low-cost interactive video system. For example, at the Sarnoff Research Center, a Digital Equipment Corp. VAX minicomputer used for early DVI research took about 30 seconds per frame to compress motion video, and many thousands of frames were needed.

Still, the slowness and high cost of computer time for compression do not necessarily make it impractical for interactive

Defining terms

Compact-disk read-only memory (CD ROM): a disk in which data bits are stored as microscopic pits and are read by a laser beam.
Interactive video: video in which the user can communicate with the video system to select material to be viewed and the way it is viewed.
Pixel: a single picture element in a digitized image composed of many thousands of such elements.

Arch C. Luther Arch Luther Associates

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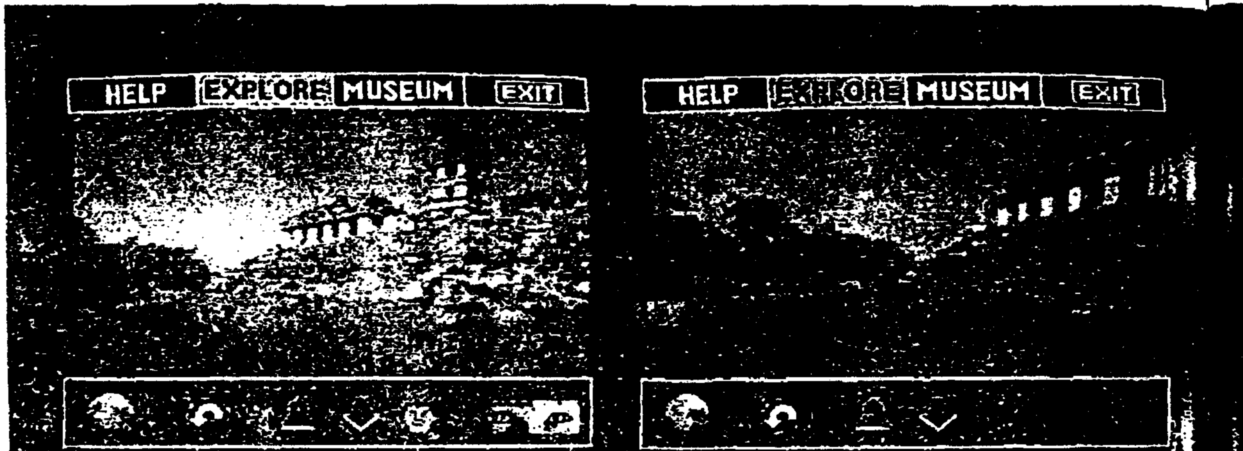


[1] One application of Digital Video Interactive (DVI) is surrogate travel: "live" motion video in which the viewer travels through a physical site, in this case Palenque, a large complex of Mayan ruins in Mexico. Travel takes place only along a preset (and invisible) path, although a viewer can reverse the visible direction of travel with the circular arrow button at the bottom of the screen. The frames shown are excerpted from a route that travels across the lawn toward the temple, then bears right and moves

video. Software for most interactive video programs can be prepared well in advance of use. The compression needs to be done only once, and the expense becomes part of the program publishing cost that is shared by users. The end-user equipment decompresses the data, and a few integrated circuits can do that.

The storage medium for the compressed video determines the degree of compression. A compact-disk read-only memory (CD ROM) was chosen for DVI technology. This medium offers a good tradeoff between performance, features, and cost. A CD ROM stores nearly 650 megabytes and reads it out at a rate of 150 kilobytes per second, which yields a playing time of up to 72 minutes.

Engineers at the Sarnoff Research Center have developed compression and decompression algorithms and a set of very large-scale integrated (VLSI) circuits for decompression. The compression process begins by digitizing original video material into picture elements: 256 horizontally by 240 vertically, a resolution slightly lower than on an ordinary television screen. At this stage, a single video frame consists of more than 180 000 bytes. The compression algorithm reduces this figure to less than 5000 bytes per frame—a ratio of more than 36 to 1.

The two decompression chips actually form a special-purpose microprocessor; the pair can be programmed to accommodate many different decompression algorithms, not just the one developed by Sarnoff engineers. Designing this versatility into the chips makes sense because there are so many strategies for video compression and decompression—and so many new strategies emerging. It would be impossible to remain competitive if a single strategy were chosen and cast in the silicon of custom VLSI chips.

At the Media Laboratory of the Massachusetts Institute of Technology in Cambridge, for example, engineers are working on algorithms for compression techniques that they hope will lead to digital movies on CDs and other media. Researchers at the laboratory are currently implementing their algorithms on PC add-in hardware, so that they can be studied in interactive use. Plans are also under way to program the DVI chips with the algorithms. Workers at the University of California, Los Angeles, Picturetel Corp., AT&T Bell Laboratories, and other laboratories large and small are developing compression algorithms for teleconferences that may offer advantages in interactive video.

Regardless of the strategy, digital video data lends itself to compression because a motion scene usually changes only slightly from one frame to the next. In a digital system, it is a simple matter to retain the previous frame in memory and compress only the differences between it and the next frame. In DVI technology, the compressed data is a stream of bits coded as a series of commands. The commands tell the chips running the decompression algorithm how to construct the upcoming frame, merging the information in the previous frame with the new information in the bit stream.

Frame-to-frame decompression, though, cannot deal with a change of scene. Frame 1 of the new sequence cannot draw on redundant data from the last frame of the preceding sequence. To handle the situation, video producers can tell the DVI algorithm to switch to a still-frame mode. It then reproduces frame 1 as a still image—a frame that does not depend on any previous frame. The still frame uses three times as much data as a normal motion frame; for subsequent frames, the algorithm reverts to the frame-to-frame mode. If a producer does not identify change points, the DVI algorithm will alter the image over several frames, producing an effect similar to a fast dissolve.

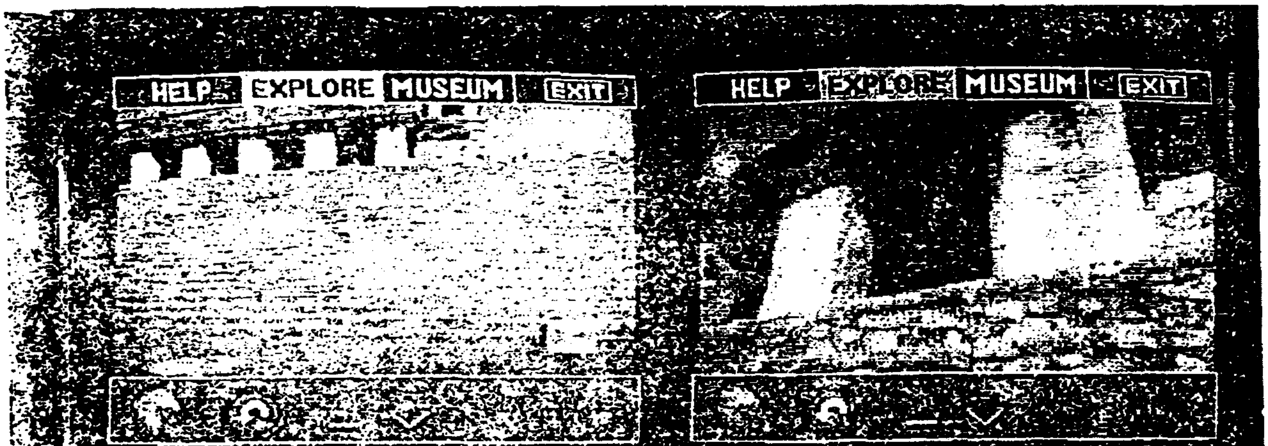
Chips for decompression

The 30-second-per-frame rate used in early experiments on DVI technology was too slow for commercial purposes. To speed up compression, Sarnoff engineers adopted a system produced by Meiko Ltd., Bristol, England, that employs 64 parallel processors and runs the same algorithm in 3 seconds per frame. Of course, more processors on the parallel machine would allow it to run faster still.

Another compression bottleneck is digitizing the analog video. For best quality, digitizing from an analog videotape source should be done in real time. Sarnoff engineers have built equipment for doing this, but the combination of real-time digitizing and multiprocessor compression means that compression is best done as a centralized service, available to anybody who uses DVI technology. GE has set up a service that produces fully compressed video for several hundred dollars per minute, a price that will drop as the number of users grows.

A centralized compression service is economical, but it hampers creativity when developers want to experiment with applications and data. Accordingly, DVI technology offers another kind of compression: edit-level video, done on the developer's DVI system in real time. Edit-level video is lower in quality than the presentation-level video made by centralized compression, but is adequate for software development.

As an option, the DVI system contains a video digitizer used in edit-level video to process live video input while the chip set runs a simplified (and not frame-to-frame) compression algorithm. The result is lower-resolution, lower-frame-rate color



up the stairs toward the pillars of the temple. The eyes in the bottom bar of the first photo indicate a point in the travel at which a user can choose to pan around a 360-degree view of the scene. This view is constructed from a fish-eye view of the entire 360-degree scene, digitized and processed to reconstruct a continuous image from a head-on perspective. The travelogue and tutorial materials were developed by the Bank Street College of Education, New York City.

video images compressed to less than 500 bytes per frame, stored on the hard disk of the user's PC. The chip set can play back the compressed images.

Users employ edit-level video to develop and test new software. When they have made their choices and polished the program, they send the final analog video through the centralized compression service. When the presentation-level compressed video comes back to them, they substitute it for their edit-level files. Their newly developed software runs just as it did in testing, but now with higher-quality video.

The heart of the DVI video display processor is two chips: one for processing images stored in memory, the other for displaying processed images. They are CMOS chips that together contain about 265 000 transistors. The set can connect to almost any computer, as long as it has the requisite computing speed and data transfer bandwidth—usually this means a 16-bit or 32-bit processor operating at a clock speed of 6 megahertz or higher.

The chip set uses its own RAM with two I/O ports and a capacity of up to 16M bytes [Fig. 3]. Like an ordinary RAM, it has a port for random-access reading and writing. This port connects to the data-bus interface of the pixel processor chip. Unlike an ordinary RAM, however, the video RAM (or VRAM) also has a port that connects an internal shift register to the display processor chip. The dual ports let the pixel processor read from and write to the VRAM while the VRAM's shift register is simultaneously sending update data to the display processor. The display processor chip can then refresh the video screen continually without interfering with the pixel processor's operation.

Flexibility through software

The complete pixel processor, which is similar to a general-purpose microprocessor, could theoretically be used to control the entire DVI system. It is more practical, though, to use a standard PC as the host for the chip set, with the pixel processor as a coprocessor. The host controls the system, manages data, and provides mass storage and a user interface. The chip set then has to be concerned only with video display functions and operates in parallel with the host.

DVI system software handles most of the details of system operation, allowing application programmers to work efficiently with simplified software. Developers are working to standardize the software interface between a programmer and the host computer, so that DVI appears the same no matter which host is used.

DVI system software uses the normal operating system of its host to communicate with the host computer and peripheral equipment. For the IBM PC AT and compatible computers, for example, DVI communicates via the MS-DOS operating system. For this environment, the DVI system software package includes a real-time module that allows audio, video, and computer tasks to run simultaneously. And when a CD ROM is used with MS-DOS, the system needs Microsoft's CD ROM extension to MS-DOS.

'Traveling' by video

While developing software and hardware for interactive video, engineers at the Sarnoff Center have also been working on ways of acquiring and using video source material. A surrogate travel application, for example, is created by going to a site and shoot-

DVI versus CD-I

Digital video interactive and compact-disk interactive technologies are quite alike. Both let users manipulate a wide variety of programming with a joystick or mouse. Both use compact disks (CDs) as a storage medium. Both produce sound as well as still and moving images.

But there are big differences, too. CD-I will be sold as a complete system consisting of equipment designed and manufactured especially for the purpose [see "Making compact disks interactive," *IEEE Spectrum*, November 1987, p. 40]. It will be aimed at the consumer market.

DVI is not a full system in the same sense. Rather, it is a technology that can be added to many different standard computers. It is sold as an add-on item for personal computers and is aimed primarily at business and industrial markets. Eventually, however, DVI is likely to be sold as a product package, including versions for consumers.

Because DVI uses a programmable video coprocessor as well as a host computer, it offers full-screen, full-motion images. CD-I is restricted to a partial screen for moving images, although it can handle simple, cartoon-like, slow-moving images on a full screen. Moreover, DVI's coprocessor can be programmed for any of a variety of decompression algorithms, while the CD-I display processor is limited to a built-in decompression scheme; a hardware change would be needed to accommodate other schemes.

CD-I is designed around the compact disk but DVI is not. Right now, CD ROMs are an ideal storage medium for DVI, but the programmable video coprocessor lets a user choose a hard disk for storage. And, when they become available, erasable optical disks can readily be adopted. —*A.C.L.*

ing videotape of all possible paths. An effective way of doing this is to take a sequence of still photographs at intervals of about 1 meter along a path. This yields approximately one frame of video for each step walked. At a resolution of 256 by 240 pixels, a CD ROM can hold compressed video for more than 40 kilometers of walking.

When the still frames are displayed in sequence at up to 10 frames per second, the viewer gets a convincing feel of actually being there and walking (or running) down the path. The viewer controls the speed and direction of movement and chooses the path and hears sounds appropriate to the location on the site.

Surrogate travel can also include panoramic views. At selected points during travel, the user can look not just straight ahead but also in any direction around a full 360-degree circle. The user

DVI: a rollercoaster to success

The crowd jumped to its feet and applause thundered as Arthur Kaiman stepped away from the podium, concluding the first live demonstration of the technology called DVI (for digital video interactive). Sarnoff researchers Larry Ryan and Arch C. Luther sat on the stage, benumbed. "I wasn't expecting the overwhelming emotional reaction," Ryan said. "I could hardly believe it was happening."

Even at the last second, it almost didn't happen.

The demonstration on March 4, 1987, the last of a series of technical advances announced at Microsoft Corp.'s second conference on compact-disk read-only memory (CD ROM) in Seattle, Wash., was the first public unveiling of a project officially begun in 1983. Its roots dated to the early 1970s, when Ryan joined the David Sarnoff Research Center in Princeton, N.J.

He worked for several years on custom chips that would link a calculator to a television and allow users to watch a TV version of a paper tape. The project was killed when a basic calculator dropped from $100 to $10 and it became clear that no one would want a calculator peripheral that cost hundreds of dollars.

Next Ryan began developing a videogame machine. Two years later, he abandoned it when he saw that other companies with similar projects had more management support than he could round up from Sarnoff's parent, RCA Corp., New York City.

Then RCA launched a home computer project. Various parts of the machine were prototyped, but in 1980 the company committed more resources to development of the videodisk and work on the home computer was terminated. Ryan began developing a method for interactive use of the videodisk—an analog device intended only for the playing of movies from beginning to end. It was feasible, he said, "but the company had no interest, so I canceled it."

At a videotex and teletext conference in Geneva, Switzerland, in the fall of 1982, one paper proposed that videotex and teletext would some day include small photographs created from bits, encoded in some way and displayed in a portion of the screen—and Ryan had an idea that would pull together all of his abandoned work.

That was the first time, Ryan told *IEEE Spectrum*, that he heard of bit-mapped digital video images generated from compressed representations. If it were possible to store a few, small pictures in a compressed digital format, he thought, why not find a means of encoding data so tightly that up to an hour of full-motion video could be stored digitally on a videodisk?

Over the next few months, Ryan made sure that the technology existed to enable decompression by a VLSI chip; that analog videodisks had enough bandwidth to support the needed data rate; and that memory costs were expected to come down enough to build an affordable frame buffer (memory where an entire video frame is stored before it is displayed). In late 1982, after asking other researchers "to check out the basic assumptions and make sure I hadn't missed something important," he went to his boss, Arthur Kaiman, Sarnoff's director of digital products research.

"I was sold on it almost instantly," Kaiman said, and he assigned six other people to the project.

Sibling rivalry

But at the same time, design began on a new videodisk player with a computer interface jack for interactive use. At first, DVI was seen as competing with attempts to make analog video more interactive, Ryan said.

By the end of 1983, Ryan's group had simulated compression and decompression of digital video on a minicomputer linked to graphics workstations, and had designed a block-level architecture that they hoped to turn into VLSI chips. They presented their work to upper management, trying to convince RCA that DVI would become its next great consumer product.

But in the spring of 1984, without warning, RCA dropped out of the videodisk business. "Here we were," recalled Kaiman, "with a technology all dressed up with no place to go. We had no support from any division in RCA, and it no longer fitted into any part of RCA's businesses."

The group quickly chose CD ROM as their base—a medium they had previously rejected because its data rate was only 1.2 megabits per second, versus almost 4 Mb/s for the videodisk. By midsummer, they had developed compression and decompression algorithms for the reduced data rate. Meanwhile, the RCA New Products Division in Lancaster, Pa., finally adopted the DVI project. Outside companies began work on applications in cooperation with RCA.

The predicted cost of the product grew. Then the home computer market went through a major shakeout, with discontinued units selling for well under $100. The New Products Division, seeing DVI as a home computer that would cost too much, pulled the plug.

The DVI group, dwindling from its 40-person high as researchers were assigned to other Sarnoff projects, retrenched, although Sarnoff management continued to back the project. The group refocused from the consumer market to commercial users, with plug-in boards for the IBM PC AT instead of a stand-alone unit. Such boards "wouldn't require a $40 million advertising budget," Kaiman said. The group also persuaded an RCA computer-aided design task force to purchase CAD software for them from Silicon Compilers Inc., San Jose, Calif., to "test" with the design of their VLSI chips.

Beat the clock

In January 1986, Kaiman recalled, to keep the project alive, he had to make "the outlandish promise that we would design chips immediately and have a working system by the end of the year."

Meanwhile, General Electric Co., Fairfield, Conn., bought RCA, and Rick Stauffer, now manager of the DVI Technology Venture, was assigned from GE's corporate headquarters to the DVI project. Kaiman took Stauffer to visit William Gates, chairman of Microsoft Corp., Redmond, Wash., who was enthusiastic about DVI's possibilities. He urged them to unveil it at Microsoft's CD ROM conference the following March. Stauffer told GE March was the time to go public, and the conference became a hard deadline.

Kaiman turned over three-fourths of his group to Luther, then a senior staff scientist at the Sarnoff center, and himself managed the chip design team. In November, one of the two chips, VDP2, arrived from the foundry and was determined to be fully functional.

VDP1 arrived in December—with a faulty interface between a memory block and a logic block on the chip. "We found the problem in a week and figured out a way to fix it via a metal mask change," Ryan said. Two Sarnoff engineers stationed at VLSI Technology Inc., San Jose, Calif., made the change during the first week of January; new chips arrived in Princeton at the end of the month. They worked.

can control the direction to experience the effect of turning around continuously, for example.

To produce a panorama, a photographer first takes a still photo of the scene through a fish-eye lens pointing straight up. A centralized processing service digitizes the fish-eye image with high resolution (at least 2000 by 2000 pixels) and divides it into pie-slice sections, meanwhile digitally converting the sections into rectangular frames. Finally, the service compresses the rectangular frames for storage on a CD ROM.

When a user wants to view the panorama, the DVI system decompresses the frames and holds them in memory. Depending on the direction the user indicates, the system digitally combines parts of two adjacent frames to make a display frame. The user seems to be turning smoothly around while seeing a seamless display.

For synthetic video, Sarnoff engineers have developed a warp algorithm to marry video textures to the surfaces of polygons on a computer-generated model. The warp algorithm might use a digitized, compressed photograph of a fabric, for example, rotating its texture and adjusting its size, so that it fits in a diamond-shaped area on the screen. A DVI system performs a single warp operation in about 10 milliseconds.

The warp algorithm can mate textures to the surfaces of a computer-generated perspective drawing of a house, so that housing developers can show prospective customers what their home might look like and offer them alternatives. The computer model of the house consists of the coordinates of points defining the outline of the house, and the user can rotate, translate, and scale the elements of the outline to represent the house as a simple wire-

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Now the DVI team had only a month to integrate the system software, debug it, and get applications running. They worked seven days a week, two to three days at a time without going home.

Then, Ryan said, they made what is usually a classic mistake. "We didn't freeze the system a week beforehand, to let the applications settle down." Instead, they tried to "tweak the hardware and software until the last minute."

"So," said Kaiman, "we were going to go to this conference and do the demo live in front of 1000 people, although we had never seen it work before. This was disaster waiting to happen."

The potential for disaster became even more real the night before the show. After Kaiman promised at a press conference that he would present the DVI system the next morning, the team tried a dress rehearsal. The system crashed over and over, never running for more than a few seconds at a time. "It was a total disaster," Kaiman recalled; at two in the morning he went to bed.

But several engineers, led by Michael Keith, stayed up all night debugging the software. They finished just before the technical announcements began. There had been no time for a test before Kaiman, Ryan, and Luther took the stage.

When the demo started, Ryan saw on his monitor that everything ran fine, but video cables had been incorrectly connected, so the screens that faced the audience were blank. The cables were quickly rerouted. Much to the trio's surprise, Keith got it going without crashing the system.

In fact, the system stayed up throughout the demonstration. Motion video from a CD ROM—technology that experts said would not be feasible until the 1990s—was born.

Running with the ball

Now what to do with it? Just after the debut, GE donated the Sarnoff Research Center to SRI International of Menlo Park, Calif. GE kept the rights to DVI, but it was more a stepchild than ever.

The positive press that greeted the debut, however, was heard at GE's highest levels. Chairman Jack Welch mandated the formation of the DVI Technology Venture (which GE now seeks to make a joint venture with other corporations).

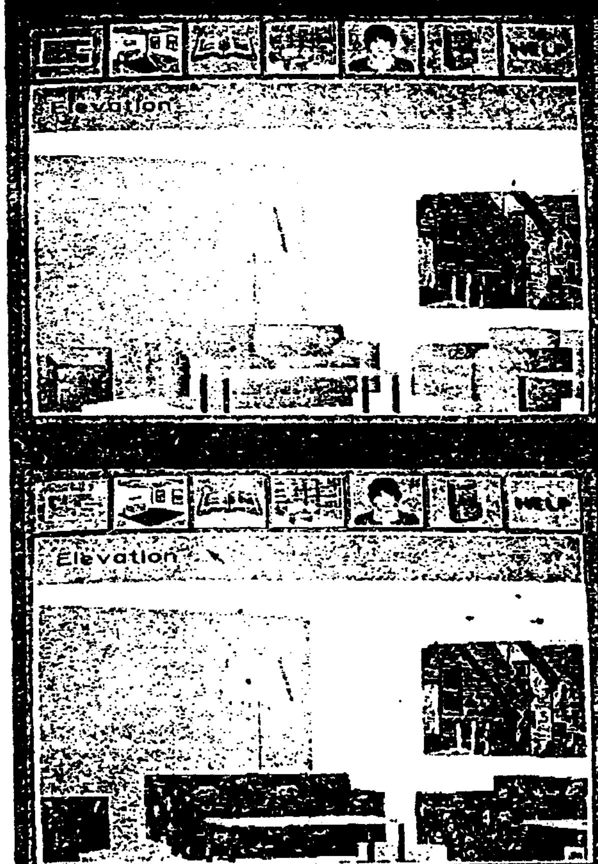
Because the group could not get a marketing staff, Kaiman said, they wrote a questionnaire on DVI's most exciting features, the markets it might serve, and desirable prices and configurations. They asked everyone who contacted them to fill it out; 4000 such contacts have been made, and group engineers still demonstrate the DVI system daily.

The first software package to be completed was "Design and Decorate," a tool for interior design and furniture firms. Ten companies are developing applications based on preliminary DVI hardware and more are expected to sign up this year. Planned products are still secret; possibilities include business and military training, interactive music videos, point-of-sale terminals, travel guides, and medical simulation. Hardware is to be on sale early in 1989.

In two years, GE expects that planned cost reductions will permit DVI products to be marketed to consumers for entertainment and education. That market holds "the most exciting applications, and sales big enough to attract the attention of major consumer electronics companies," said David Ripley, Sarnoff's manager of DVI applications development.

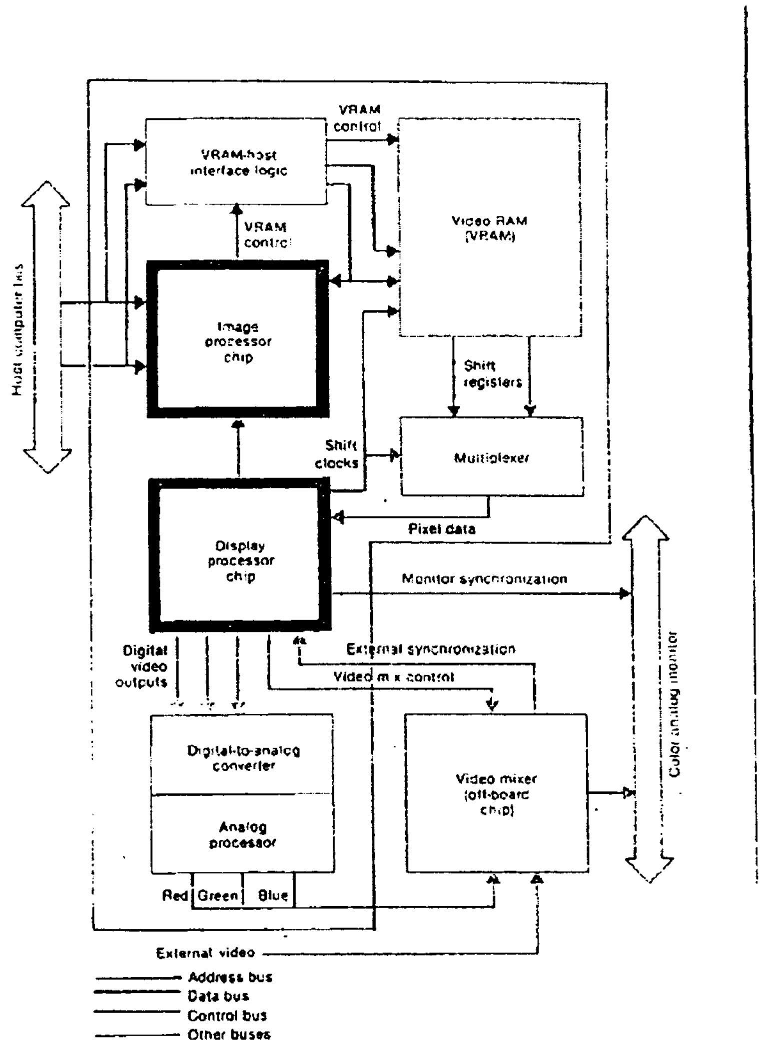
Larry Ryan may finally get a product out the door.

—*Tekla S. Perry, Field Editor*



[2] "Design and Decorate," a prototype DVI software tool, helps professional interior designers try out ideas and communicate them to customers. Alternative upholstery fabrics may be compared in a fully furnished setting, for example. Designers can select from a massive catalog of furnishings, fabrics, colors, and room shapes on a single compact-disk ROM.

[3] This video circuit board is one of three that make up DVI hardware to be added to the use's host computer; the other boards are for audio and utilities. Two custom ICs on the video board—the image processor chip and the display processor chip—form a coprocessor that functions in parallel with the host processor, typically a personal computer. Another important component is the video RAM (VRAM), which uses two ports to speed up operation—one for address and data I/O and one for picture-element data outputs from its internal shift registers.



frame from any point of view.

The warp algorithm then fills in the wireframes with processed photographs or drawings of front, side, and roof selected from a library stored on the CD ROM. The algorithm takes care of fitting the rectangular images into the distorted shapes of the perspective drawing. Details of bricks, windows, shingles, and doors become readily available without having to be stored in the computer model.

The warp algorithm is fast enough to construct elaborate images with only a barely noticeable delay. Complex renderings of room scenes for interior design can be displayed in a few seconds. Customers for home furnishings can easily rearrange, reupholster, and refinish furniture on the DVI screen.

For this application, the DVI system stores compressed photographs and three-dimensional drawings of furniture and accessories and compressed photographs of fabrics, wood finishes, and painted surfaces. The warp algorithm combines them as the user directs. The algorithm even takes into account the direction and brightness of lamps and windows to shade objects realistically [Fig. 4].

To probe further

For information on the availability of hardware, software, and documentation for DVI technology, contact the GE DVI Technology Venture, David Sarnoff Research Center, Princeton, N.J. 08543; 609-734-2211.

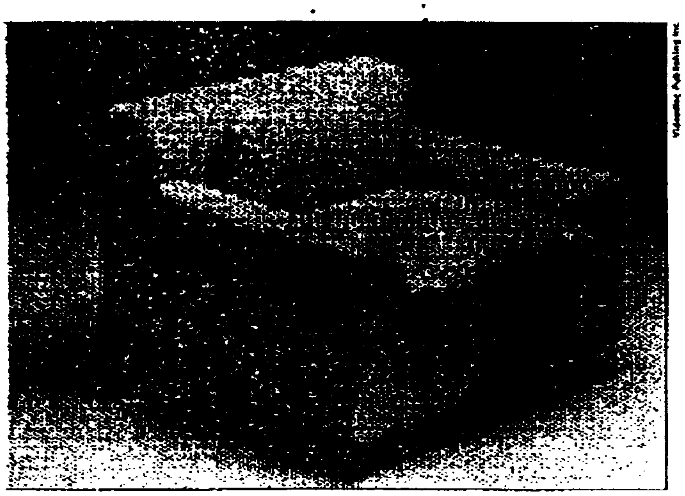
Arch C. Luther's new book, ***Digital Video in the PC Environment*** (McGraw-Hill, New York, 1988), tells how to use video and audio with PCs. It gives the theoretical background of both analog and digital video, explains DVI technology, and describes DVI software in detail.

A. N. Netravali and J. O. Limb survey digital video and video compression in "Picture Coding: A Review" in *Proceedings of the IEEE*, March 1980 (pp. 366–406).

J. D. Foley and A. Van Dam's *Fundamentals of Interactive Computer Graphics* (Addison-Wesley, Reading, Mass., 1982) is a basic reference on computer graphics techniques.

CD-ROM Review covers activities and developments in the CD ROM industry. Microsoft Press, Redmond, Wash., collects wide-ranging papers on CD ROM multimedia systems in *CD-ROM: the New Papyrus* and *CD ROM Optical Publishing*.

Two articles in the April 1986 *IEEE Spectrum* describe CD ROM technology and applications: "The compact disk ROM: how it works," by Peter Pin-Shan Chen, and "The compact disk ROM: applications software," by Tim Oren and Gary A. Kildall (pp. 44–54).



[4] DVI generates realistic shadows on objects by taking into account the direction and intensity of lighting. If this chair is reoriented, its new position with respect to the light source will replace the previous shadows with new ones.

About the author

Arch C. Luther (F), president of Arch Luther Associates, Merchantville, N.J., is a consultant, writer, and software designer. He worked on DVI technology as a senior staff scientist at the David Sarnoff Research Center in Princeton, N.J., and spent many years as an engineer and manager in the Broadcast Systems department of RCA Corp., New York City. He has a BSEE degree from the Massachusetts Institute of Technology, Cambridge. ◆